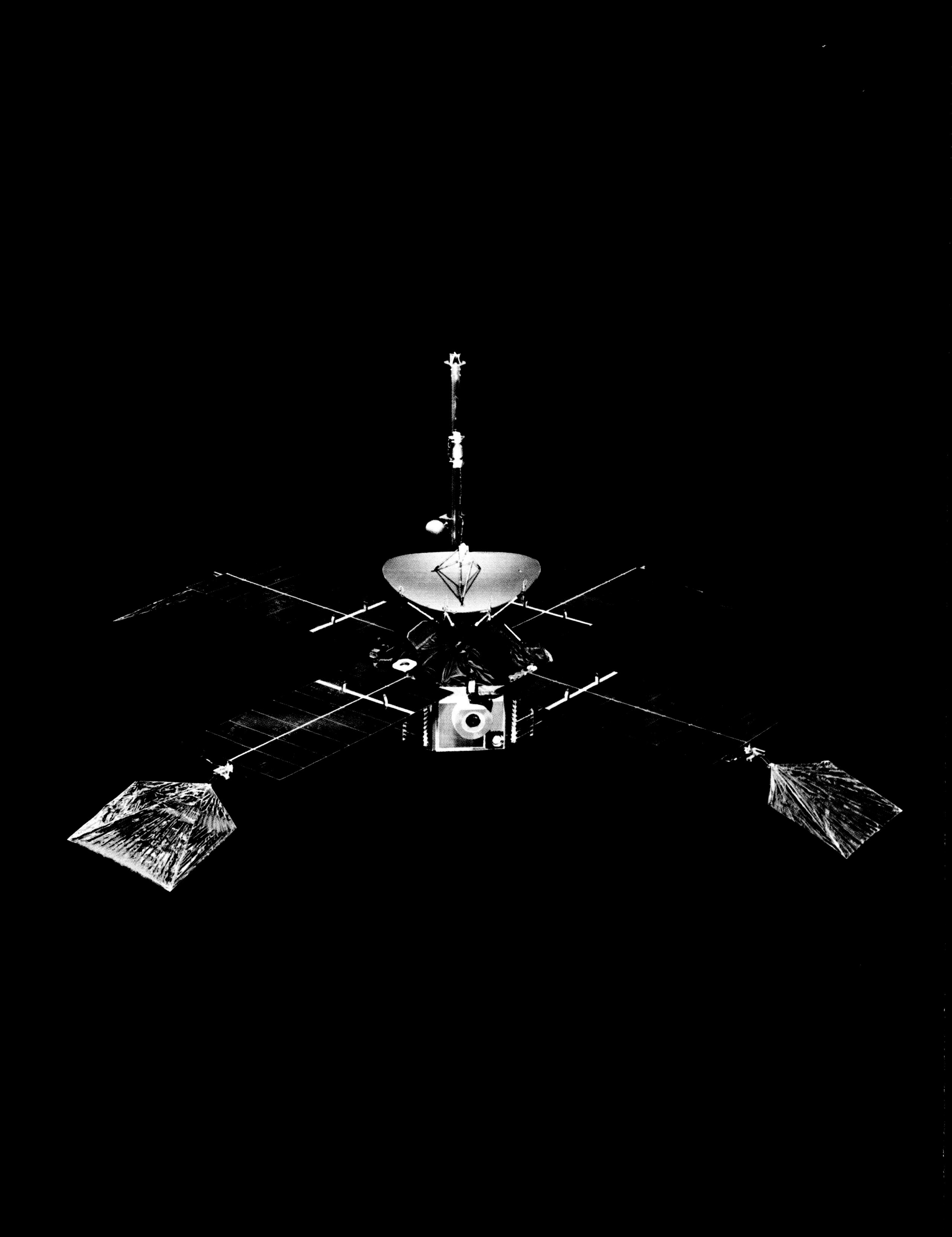
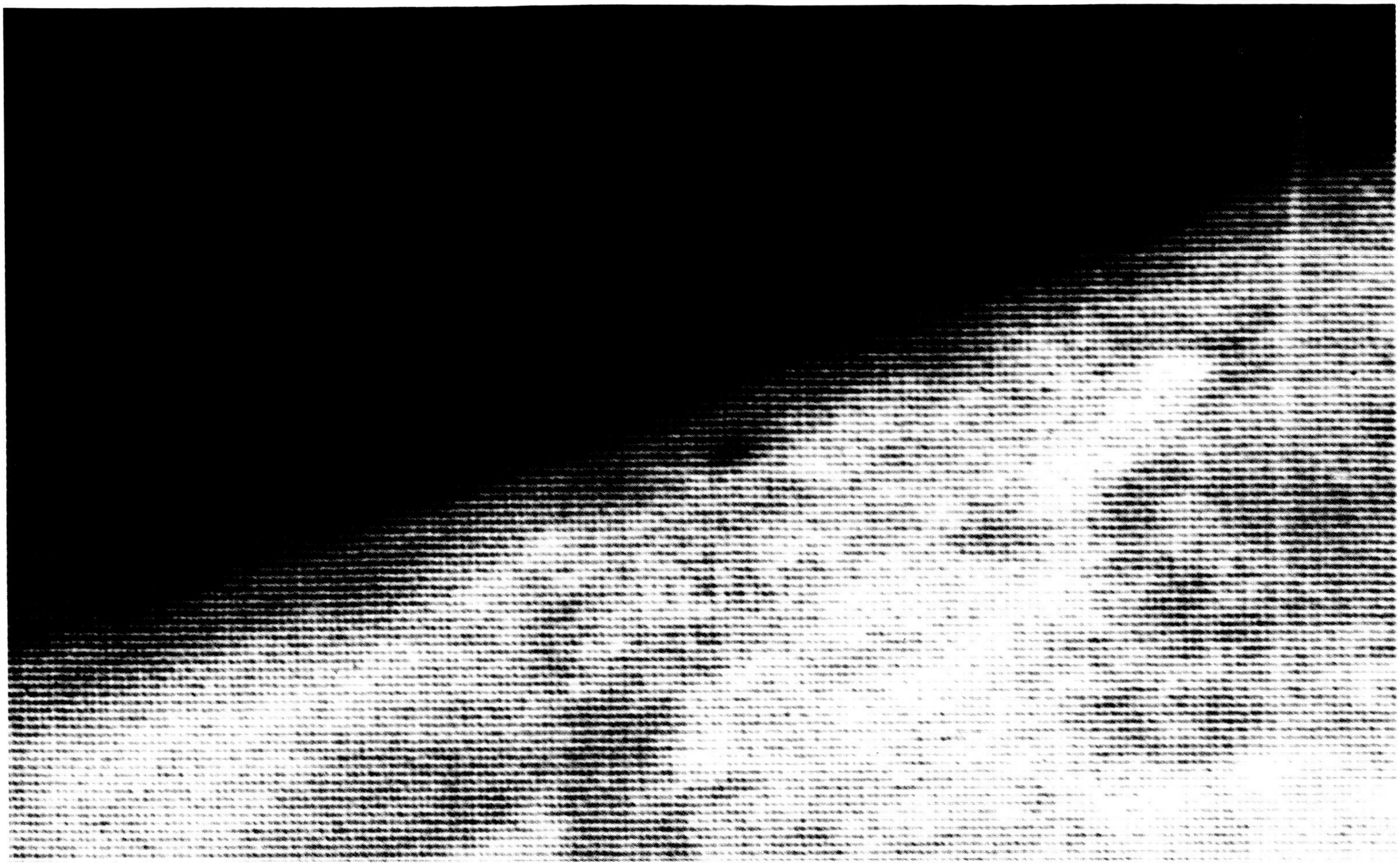
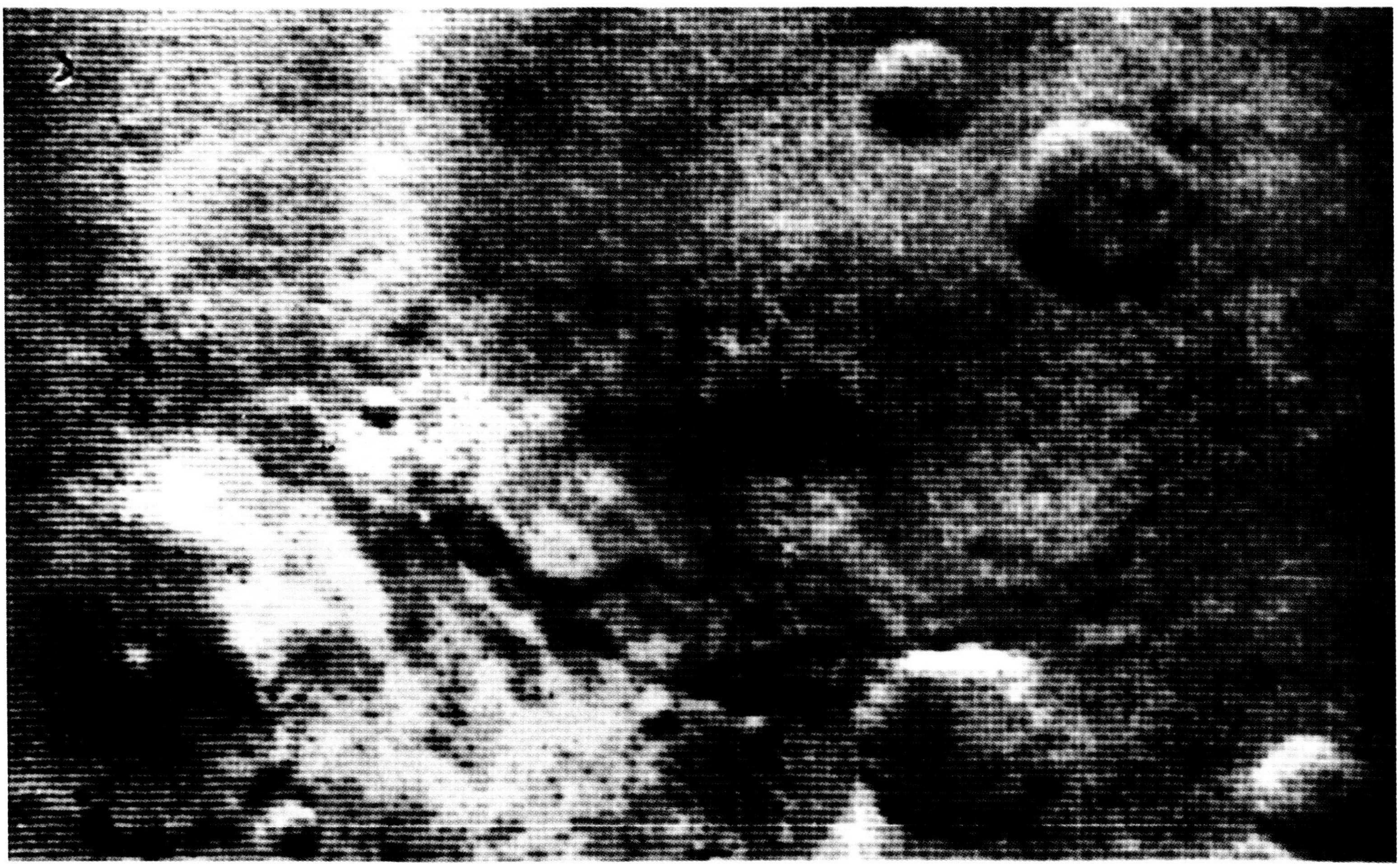
MARINER: Journey Around the Sun

The Mariners are a series of lightweight unmanned deep space probes in constant communication with the Earth, designed for planetary flyby missions; they all derive their power from the Sun and are capable of performing mid-course maneuvers. It is the objective of the Mariner missions to conduct scientific observations in the vicinity of the near planets and to explore the interplanetary environment, with the secondary goal of developing the equipment and techniques involved in the construction of spacecraft for long-distance, long-duration flights. In addition, the advances in space science and space technology achieved by the Mariner series will have application to a variety of scientific and technical endeavors for many decades to come, as will the refinement of celestial parameters and general knowledge of the solar system that has resulted and will continue to result from the flights of the Mariners.



On May 3, 1966, the new NASA/JPL 210-foot antenna at Goldstone, California, picked up a telemetry signal from over 197 million miles out in space. It was the faint signal of Mariner IV, which for many months had been beyond the reach of the 85-foot antennas that had tracked the spacecraft on its journey to Mars. Since the end of the Mars mission, only the carrier signal had been detectable on Earth. Now the telemetry data could again be extracted and analyzed—the spacecraft's message could be understood and interpreted. The result was an unexpected report on the environment of deep space and on Mariner's own remarkable operating performance.


Mariner IV photograph of Mars, Picture No. 1

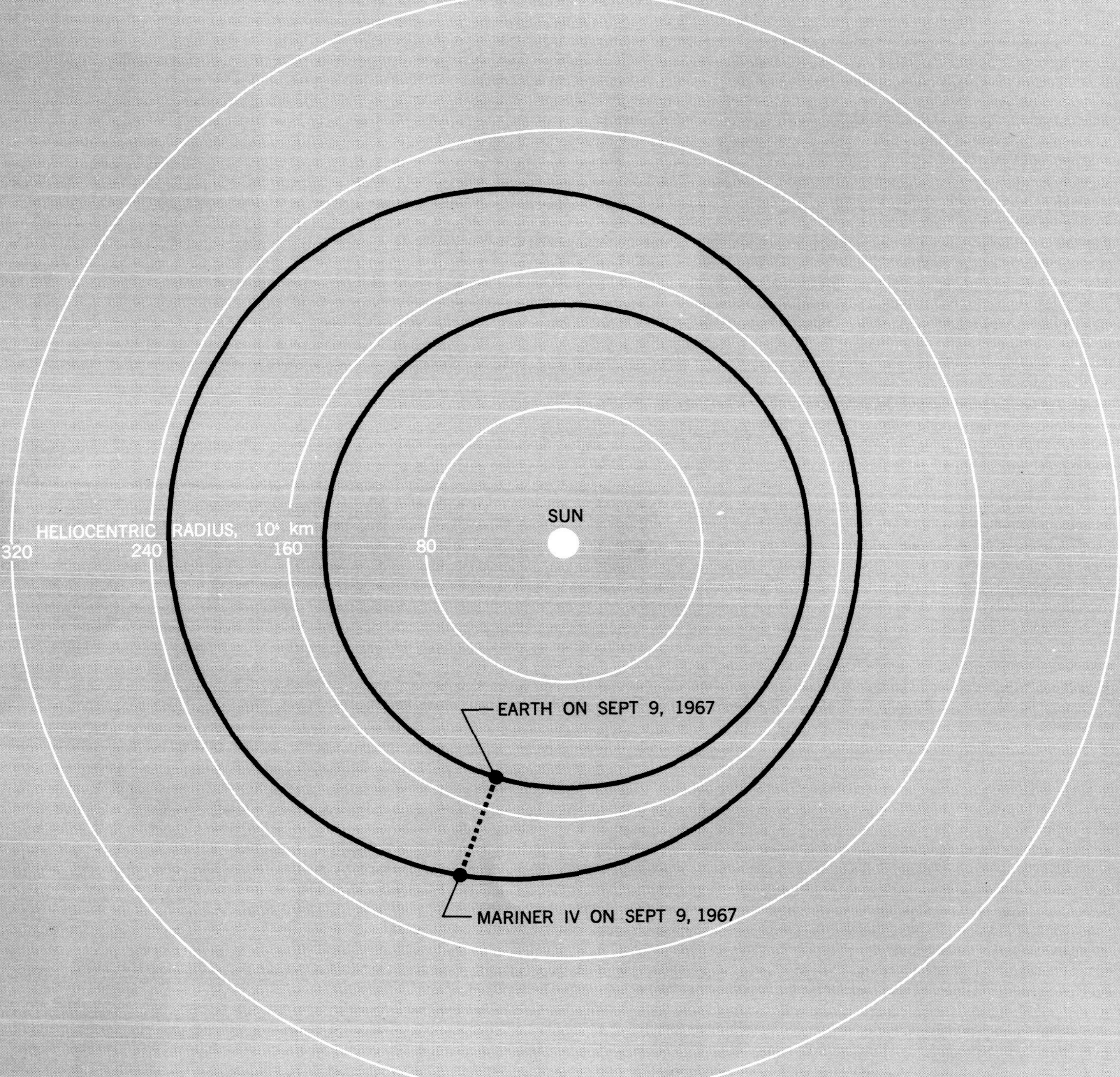
Mariner IV photograph of Mars, Picture No. 11


First Trip to Mars

The journey of NASA's Mariner IV began on November 28, 1964, when it was launched on a trajectory to Mars. Its main objective was to fly close enough to the planet to obtain and return information about Mars and its vicinity. During and after a trip that took 8 months and covered 325 million miles, Mariner sent back to Earth a wealth of data about interplanetary space and about the environment of the planet. It took a total of 21 unprecedented close-up television pictures of the Martian surface. Furthermore, it reported back on its own condition and the functioning of its systems and instruments. The results indicated nearly perfect spacecraft performance.*

The stations of the Deep Space Network had been tracking the probe faithfully since launch, and they continued to follow it for 2½ months after its encounter with Mars. The spacecraft was transmitting over a high-gain antenna that focused the signal into a narrow but powerful beam. The antenna, however, had a fixed position on the spacecraft, and unless it was pointing at the Earth, the signal could not be picked up by the conventional equipment of the Deep Space Network. Mariner also carried a low-gain antenna. This type of antenna transmits the radio signal over a broad area; it does not have to be aimed so precisely, but its power is not concentrated and the received signal is therefore weaker. On October 1, when the high-gain antenna was no longer pointing at the Earth, the received signal became too weak to produce meaningful information. On that date, the spacecraft's transmitter was switched from the high-gain to the low-gain antenna, the ground equipment was turned off, and the first chapter in the life of Mariner IV was ended.

*For further details, see *Report From Mars: Mariner IV 1964-1965*, Jet Propulsion Laboratory, NASA EP-39; available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.



SUN
HELIOCENTRIC RADIUS, 10^6 km
320
240
160
80
EARTH ON SEPT 9, 1967
MARINER IV ON SEPT 9, 1967

Mariner IV orbit around the Sun

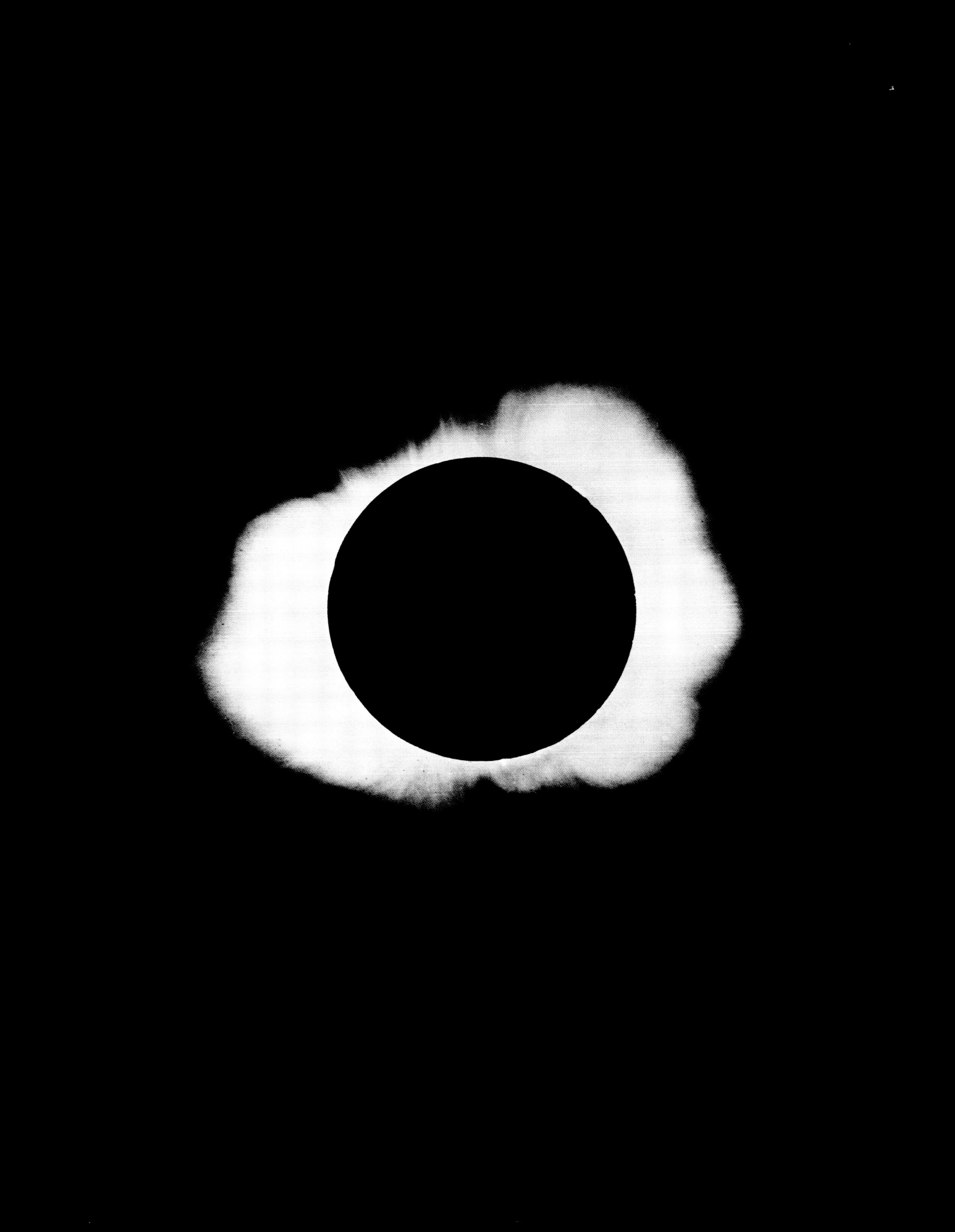
Keeping Track

Having successfully completed its designed mission, Mariner IV continued its journey around the Sun. If Mariner's systems kept on operating, and if the signal could be tracked from time to time, the spacecraft could become a coherent radio source—a radio beacon in deep space.

The first attempt to receive a signal was made on November 1, 1965. On that date, the Deep Space Station at Goldstone turned on its receiver, slewed its antenna to the proper position, and picked up once again the unmistakable Mariner signal. To be sure, it was a weak signal, but it told a great deal. It indicated, for example, that it was still carrying telemetry information, even though that information could not be deciphered. But the fact that there was a signal at all meant that Mariner was generating power; therefore, it must still be facing the Sun. And if it was facing the Sun, then the attitude-control system—the mechanism that kept the spacecraft locked in position with respect to the Sun—was still functioning. Furthermore, the solar cells must be working, and the transmitter must still be operating.

Mariner was designed and built for an 8-month trip through the environment of space. Although it successfully completed its original mission, no one knew how long the machine would continue to function properly. In December, the Deep Space Station at Goldstone again tuned in on the signal from Mariner, and again the indications were positive. Mariner was still working, still transmitting. After that, the spacecraft was checked about once each month, with the same favorable results.

During this period, a number of commands were sent to the spacecraft in order to keep it fixed on the star Canopus, which it had been designed to use as an attitude-control reference. The commands were sent blindly; since telemetry could not be extracted from Mariner's signal, there was no way of telling whether the spacecraft had accepted and acted upon the commands.



Solar corona

Through the Corona

The fact that Mariner remained in good working condition as it traveled around the Sun provided scientists with an opportunity to perform a new kind of experiment. The orbit it was following would take the spacecraft behind the outer atmosphere of the Sun—the corona; if Mariner's signal were changed in some way as it passed through the corona, perhaps it would provide us with new and significant information. A similar occultation experiment had been successfully performed at Mars and had produced important information about the Martian atmosphere.

There would be serious difficulties connected with such an experiment, however. The deep space tracking antenna could not point directly at the Sun, because the radio noise generated by the Sun would drown out any other signal. Furthermore, it would be extremely difficult to determine just how much of the signal distortion came from the corona and how much from the spacecraft transmitter, the ground receiver, or the tracking antenna.

In spite of all the difficulties, the experiment was begun on March 26, 1966. A radio signal from the 100-kilowatt transmitter at Goldstone was sent through the corona to the spacecraft. The spacecraft returned the signal, again through the corona, and it was picked up by the new 210-foot antenna. The returned signal was then analyzed. The experiment was repeated frequently between March 26 and April 12, when the spacecraft had passed beyond the corona. The results, while still inconclusive, are extremely interesting. The signal was strongly distorted by the solar corona—a piece of information that will be useful in the design of future missions and may add to our understanding of the physics of the corona. It was the first time that communication had been established with a man-made object on the opposite side of the Sun.

The experiment was significant in yet another way: it employed the new 210-foot tracking antenna. Although the 210 had not been fully completed at the time of the experiment, it was used, under "laboratory" conditions, because without the increased gain and narrower beamwidth it provided, the experiment could not have been performed to begin with.

The 210

It had long ago become evident to scientists and engineers that the value of a spacecraft depends not only upon the amount of information it is capable of transmitting but also upon how much of that transmitted information can be received on Earth. Unless we can follow and control its progress from the Earth and receive and analyze the data the spacecraft generates, even the greatest advances in spacecraft engineering are of little practical use to us. It is therefore vital that the development of Earth-based tracking instrumentation and facilities keep pace with the refinement of spacecraft technology. The termination of intelligible communication with Mariner IV on October 1, 1965 demonstrated that the reach of the existing Deep Space Network antennas was not sufficient to keep up with the distances advanced spacecraft were capable of traversing. Either spacecraft power would have to be increased, or larger Earth-based antenna systems would have to be used.

Although no one had anticipated Mariner's remarkable performance, it had already been decided to increase the capability of the Deep Space Network to meet the requirements of future spacecraft. Construction of the Goldstone advanced antenna system was begun nearly three years before the launch of Mariner IV. Its design concept was based on well established antenna designs—in particular, the 85-foot antennas of the Deep Space Network and the radio-astronomy antenna at Parkes, Australia. The new system employs basically the same operating and signal-processing techniques as these smaller antennas, but it has six and a half times more receiving sensitivity than its predecessors, and its transmitted beam is six and a half times more concentrated. This capability extends the tracking period, and hence, the useful lifetime of a spacecraft, by nearly two and a half times. Under certain conditions, it can reach the edge of our solar system.

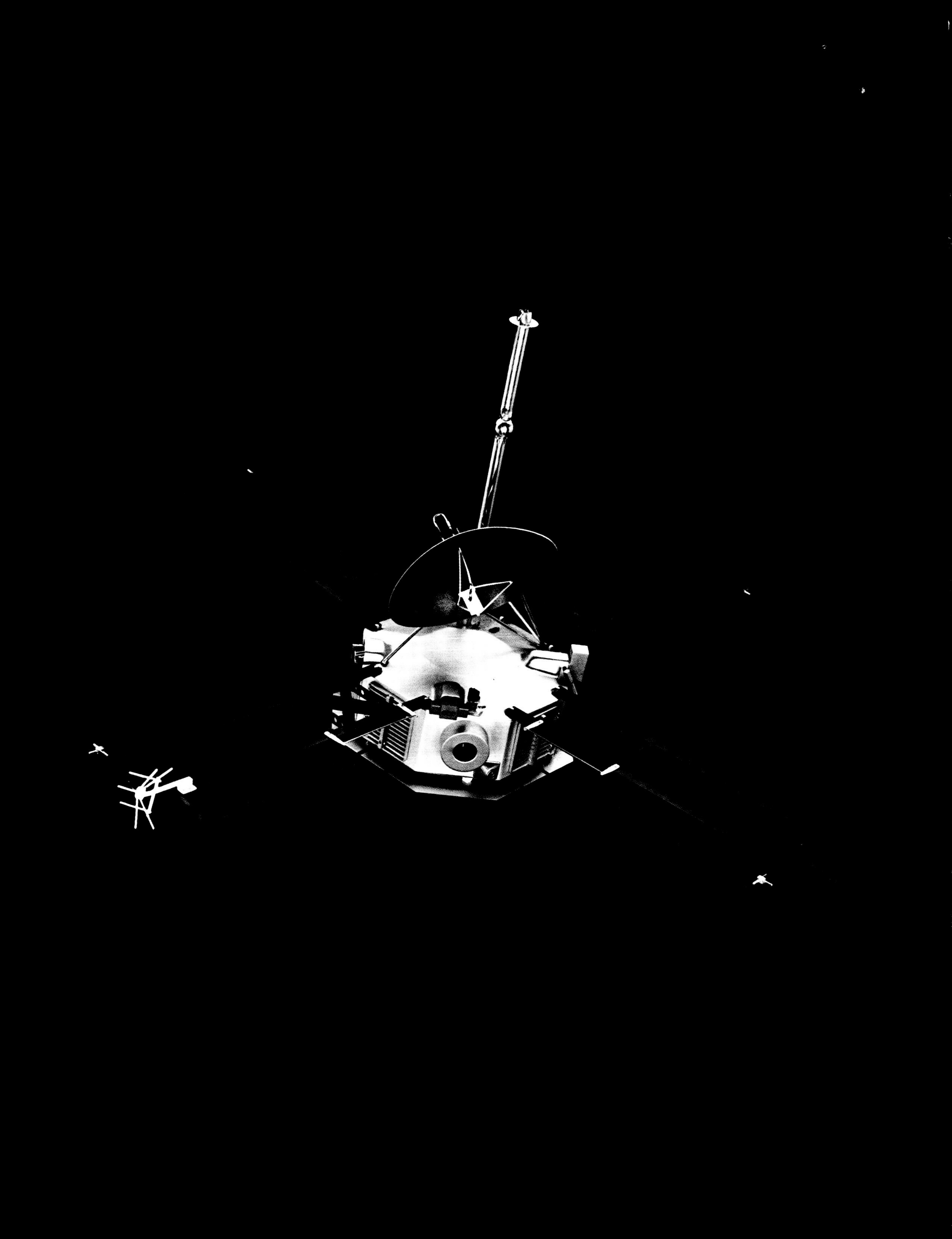
The giant reflector of the new space tracker has a diameter of 210 feet, and, together with its supporting structure, weighs over 5 million pounds. In spite of this enormous weight, it can be rotated in a complete circle and its position can be changed from horizontal to vertical in 3 minutes. It is capable of pointing at a moving target with a precision equivalent to that needed to put a bullet inside a thimble at 200 feet.

Mariner IV telemetry being analyzed at the JPL Space Flight Operations Facility

Mariner Reports Again

On May 3, May 21, and again on June 5 and July 1, the new tracking antenna was used to pick up the signal from Mariner IV. Now there was no solar corona to interfere with or distort the radio waves, so that the signal was interpretable even though it was barely above the noise level. The telemetry information was extracted from the signal and analyzed, and the performance of the spacecraft was evaluated from the resulting information, just as it had been during the mission to Mars. By this time, no one was surprised when the results indicated that all systems were working properly. The temperature was within 2 degrees of the expected value; tape recorder pressure was normal; the radio transmitter was working well; everything was as it should be. The signal also indicated that out of the 12 blind commands sent to Mariner earlier, all but one had been received. The star sensor was not locked onto the star Canopus, and while this was an unfortunate loss in terms of celestial mechanics, it did not affect the functioning of the spacecraft or of the science instruments. By May 21, Mariner had been in space for 539 days and had traveled nearly 740 million miles.

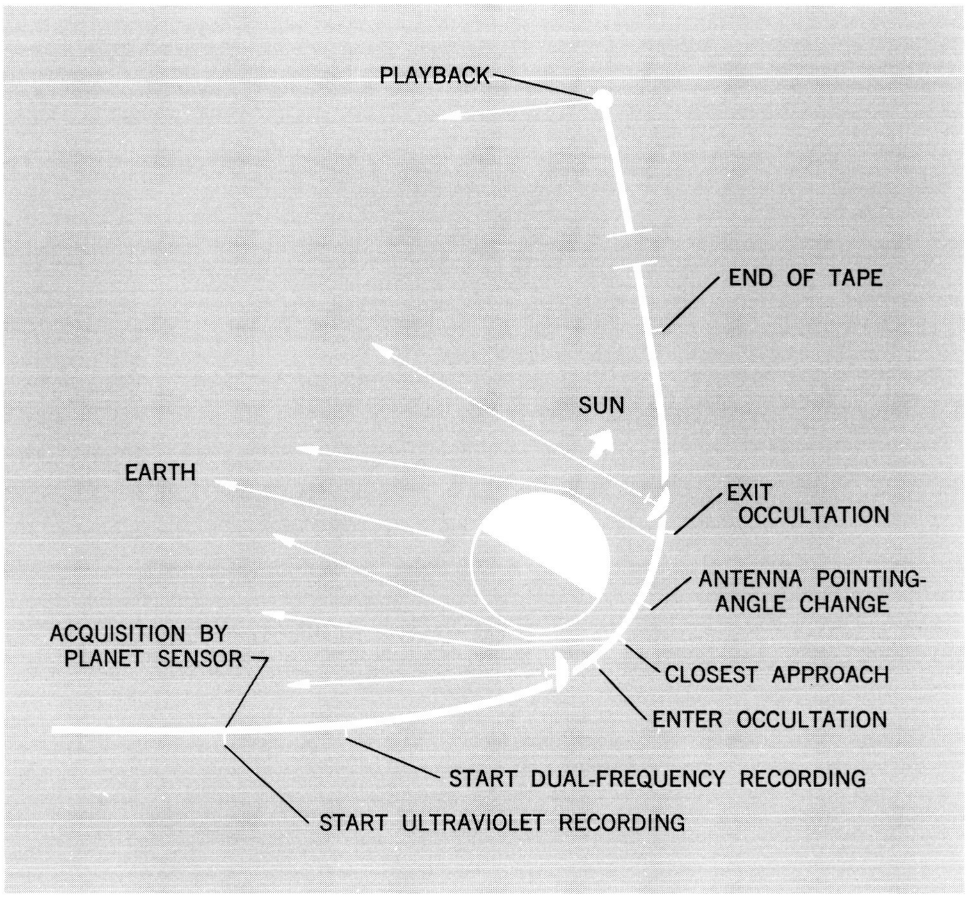
Monday, June 6, 1966, was a special day in the life of Mariner IV, for it was on that day that the probe completed a full orbit around the Sun.



To Venus: Another Mariner

In June 1967, another Mariner spacecraft will be launched on a trajectory that will bring it within some 2000 miles of the planet Venus. The launch vehicle for the Mariner Venus 67 mission will be an Atlas D/Agena D combination, the same vehicle that was used for Mariner IV. The Agena stage will be slightly modified to meet the requirements of the Venus mission. The spacecraft that will perform this mission is closely related to Mariner IV — it is, in fact, a spare from the Mars mission, modified for the flight to Venus. One of the objectives of the 1967 Venus mission is to demonstrate the feasibility of converting a spacecraft designed to investigate the planet Mars into one that can conduct similar investigations of the planet Venus. The primary scientific purpose of the mission is to obtain data about the planet and its environment and to add to our knowledge of the interplanetary medium between the Earth and the Sun. A further significant contribution to be made by Mariner Venus 67 is the expected improvement in the science of orbit determination and the accuracy of space navigation.

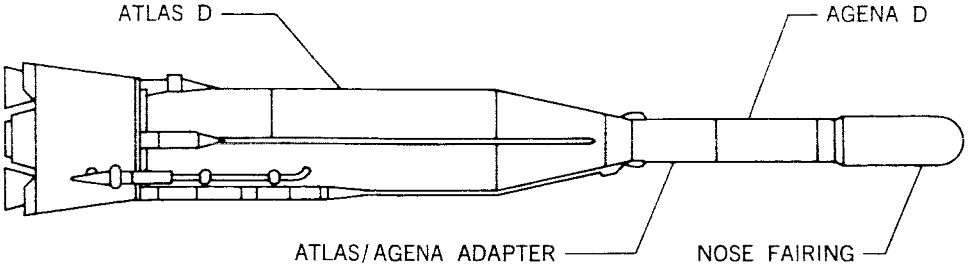
Because Mariner Venus 67 will be traveling toward the Sun rather than away from it and will be encountering different environmental conditions, several of the spacecraft components and experimental instruments will have to be changed or relocated from the original Mariner Mars design. For example, the total area of the solar panels will be reduced, their structure modified, and the configuration of the solar cells adapted to minimize heating effects. So that the antennas can function at top efficiency with as little obstruction by the spacecraft itself as possible, the attitude of Mariner Venus 67 will be opposite from that of Mariner IV — what is "top" for the Mars probe will be "bottom" for the Venus craft. This change in orientation, as well as the different temperature conditions and degrees of solar intensity to which the spacecraft will be subjected, will require changes in thermal shielding and other temperature-control devices. In addition, the position of the trapped radiation detector will be reversed to have the same solar direction as on Mariner IV, the plasma probe will be relocated to permit an unobstructed view of the Sun, and the position of the ultraviolet photometers will be fixed so that the instruments face the planet at encounter.



Venus encounter trajectory

Some of the science instruments carried on Mariner Venus 67 will be identical to those of Mariner IV, and some will be entirely new. The experiments to be performed will include investigations of the interplanetary magnetic field, the solar wind, the distribution of hydrogen and oxygen in the upper atmosphere of the Earth, charged-particle fluxes, solar X-rays, the abundance of electrons and hydrogen ions in space, and the magnetic field configuration near the planet. When the spacecraft encounters Venus, a number of additional experiments will be performed to investigate the concentration of hydrogen and oxygen in the exosphere, the electron concentration in the ionosphere, the density of the atmosphere at various levels, and the diameter and mass of the planet.

The Venus mission will also provide an unusual opportunity to enhance our knowledge of celestial mechanics. It will, in fact, be the first time that the investigation of celestial mechanics will be approached as a scientific experiment. The close proximity of the spacecraft to the planet will have a significant effect on the spacecraft's orbit, which, after the encounter, will bring Mariner closer to the Sun than man has ever before penetrated. By correlating the



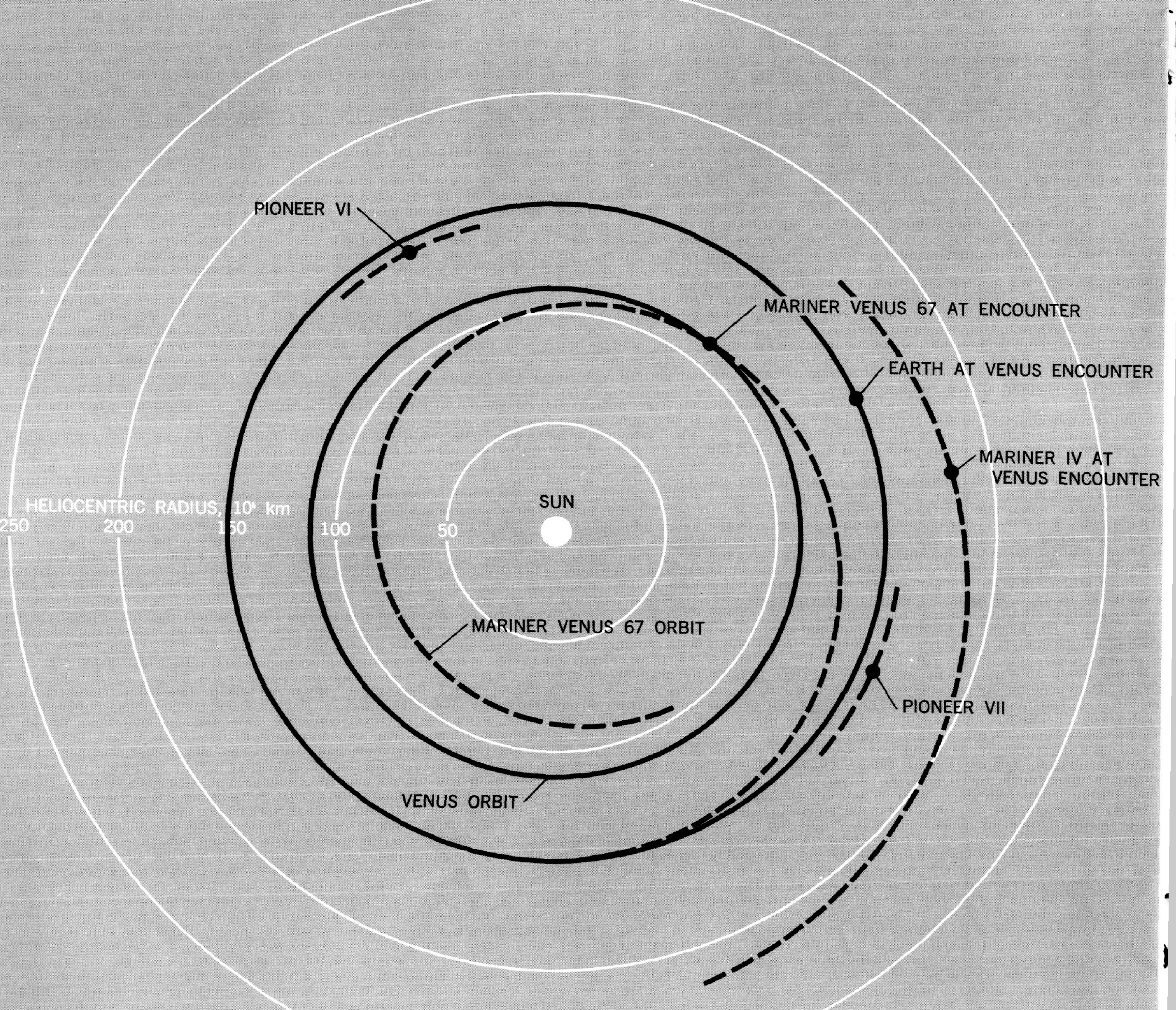
Atlas/Agena launch vehicle

new orbital data with the data available from earlier missions, scientists will be able to obtain more accurate information, not only about Venus but also about the Moon and the Earth. An attempt will be made to continue the tracking of Mariner Venus 67 for as long as possible after encounter, since every additional day of telemetry received and analyzed may mean further refinement of our knowledge of the solar system.

A Comparison

	Mariner IV	*Mariner Venus 67**
Science experiments	Trapped radiation detectors Helium magnetometer Solar plasma probe Cosmic ray telescope Cosmic dust detector Ionization chamber S-band occultation Television	Trapped radiation detectors Helium magnetometer Solar plasma probe Ultraviolet photometers Dual-frequency occultation S-band occultation Celestial mechanics
Solar panels	70 square feet total area 28,224 solar cells	43.6 square feet total area 17,640 solar cells
Spacecraft weight	574 pounds	543 pounds
High-gain antenna	Fixed position	Movable to two positions
Solar vanes	4	None
Tape recorder	12.84 inches/second tape speed 8⅓ days playback time 10,700 bits/second record rate 5,250,000 bits capacity	0.08 inches/second tape speed 32 hours playback time 66⅔ bits/second record rate 960,000 bits capacity
Flight time to encounter	228 days	114–130 days
Communication distance at encounter	216,303,650 kilometers (134,401,000 miles)	79,000,000 kilometers (49,000,000 miles)
Closest approach distance	6114 miles	1875 miles

*Prelaunch estimates.


PIONEER VI
MARINER VENUS 67 AT ENCOUNTER
EARTH AT VENUS ENCOUNTER
MARINER IV AT
VENUS ENCOUNTER
SUN
HELIOCENTRIC RADIUS, 10⁶ km
250
200
150
100
50
MARINER VENUS 67 ORBIT
PIONEER VII
VENUS ORBIT

1967: A Busy Year

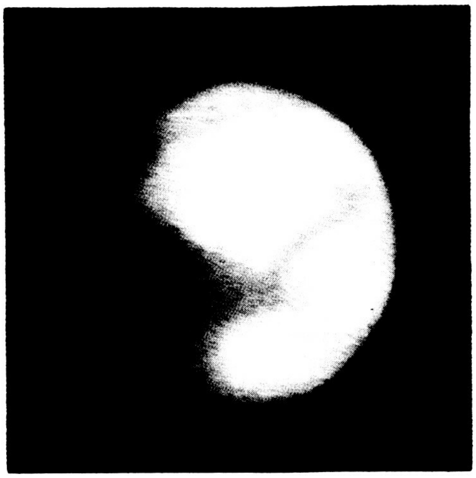
1967 will be a year of increasing solar activity. The effect of this activity on the interplanetary medium is of great scientific interest. Pioneer VI and Pioneer VII, launched in 1965 and 1966, respectively, will be in orbit around the Sun in 1967, and the simultaneous presence in space of Mariner IV and Mariner Venus 67 will provide an unprecedented opportunity to take scientific advantage of this part of the 11-year solar cycle. The closest approach to the Earth of Mariner IV will occur on September 9, and there are plans to track the spacecraft continuously for a few weeks during the Summer of 1967, when its signal will be strongest. An attempt will be made at that time to conduct several engineering experiments in addition to receiving interplanetary science information. This means that the Deep Space Network will be tracking the two spacecraft—one traveling between the Earth and the Sun and the other outside the Earth's orbit—at the same time. The fact that scientists will be able to correlate the data from several different areas in space will greatly increase the value of the information received from each spacecraft.

The 1967 activities will be based on past experience in the field of space flight operations. Both the Mariner Venus 67 mission and the reacquisition of Mariner IV will be conducted by the same team responsible for the Mars mission, applying the same techniques that were used at that time.

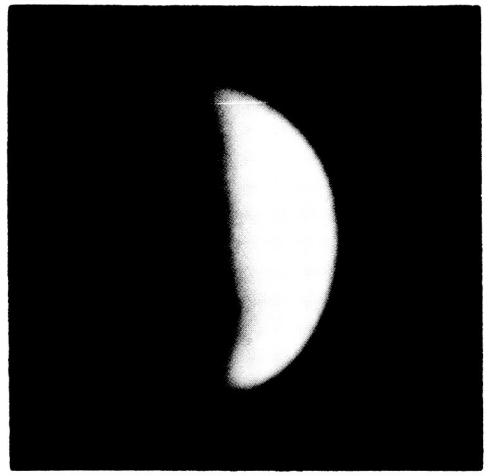
A Summing Up

Mariner IV has drastically revised our ideas about Mars and has increased our knowledge of the solar system; it graphically demonstrates the continuing advances that are being made in spacecraft technology; and it has even added to our store of information about the Earth. Among the many things that we have learned as a result of Mariner's journey around the Sun are the following.

Mars has a relatively thin atmosphere, and there is no detectable magnetic field within 6000 miles of the planet. The Martian surface is cratered and is more Moonlike than Earthlike in appearance. In addition to this entirely new information, we have also learned more about the mass of Mars and of the Earth and about their exact sizes, locations, and orbits. We have been able to redefine radial locations of points on the Earth and to refine our knowledge of celestial parameters such as the astronomical unit. We have new information about the activity of the Sun, the particles it ejects into space, solar and galactic cosmic rays, and the solar wind. We have a better understanding of interplanetary magnetic fields, cosmic dust, and trapped radiation in the vicinity of Earth and Mars.



Mars



Venus

In returning these scientific data to Earth, Mariner IV has proved above all else that it is an extremely reliable spacecraft. Since launch (to June 5, 1966), its various subsystems have accumulated a combined total of 242,500 operating hours. Broken down into key electronic part operating hours, this figure means over 42 million transistor, 145 million resistor, 59 million capacitor, 89 million diode, 5 million transformer, and 1 million relay part hours, with but one failure—a resistor on the plasma probe experiment. Based on present information, failure rates computed from these figures are either equal or superior to those of any other complex electronic system continuously functioning in space.

Only a small portion of the data transmitted by Mariner IV has been analyzed and interpreted; many more months will be required to complete the task. Furthermore, as long as Mariner IV continues to function, it will continue to provide all elements of NASA with information, both about itself and about hitherto unexplored regions of interplanetary space.

Mariner Venus 67 may modify our ideas about Venus just as Mariner IV changed many of our concepts of Mars. Because we know even less about Venus than we did about Mars, it is reasonable to assume that we shall obtain much new, and perhaps unexpected, knowledge about the planet. In addition to the technical and engineering information about the spacecraft itself and spacecraft navigation in general, we expect to learn more about the size and mass of Venus, the effects of various interplanetary phenomena in the vicinity of the planet, and the scale height, density, and composition of the planet's atmosphere. We anticipate improvements in the ephemerides of Venus and of the Earth, further refinement of the astronomical unit, and more data about the extent of the Earth's hydrogen cloud. In the course of its journey around the Sun, Mariner Venus 67 should also enable us to draw some conclusions about the orbital perturbations of the planets.

Continuing activities in the Mariner series are being conducted for the National Aeronautics and Space Administration's Office of Space Science and Applications by the Jet Propulsion Laboratory. They are made possible by the support and assistance of scientific institutions, industrial concerns, and government agencies, including NASA's Lewis Research Center and their prime contractors, Lockheed Missiles and Space Corporation and General Dynamics/Convair; Goddard Space Flight Center and agencies at Cape Kennedy; the agencies of the Australian, South African, and Spanish Governments which operate overseas space communication stations; many hundreds of American industrial contractors and vendors; and a number of scientists in various fields of endeavor.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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